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Avoiding dangerous climate change by induced technological change:

scenarios using a large-scale econometric model

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The other contributors to the main paper reporting the results are Jonathan Köhler, Haoran Pan, Rachel Warren and Sarah Winne.

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Outline

- The global problem
- Modelling technological change:
  - the equilibrium (CGE) approach
  - an econometric, demand-led approach
- An integrated model
- Scenarios and indicative results
- Conclusions

The stabilization problem

- Deep-rooted carbon “addiction”
  - but many plausible low-carbon options
  - and long periods to adjust
- A high-carbon future seems likely
  - large coal reserves are known to be available and are likely to be used in most global energy scenarios e.g. IEA Energy to2030
  - with high oil prices, coal becomes more competitive
- Carbon taxes are efficient but unlikely
  - PR campaigns have put taxes off the agenda
  - and international equity schemes face opposition
- The research agenda
  - technology-economy interactions and emission trading

Conclusions from a meta-analysis* of mitigation-cost literature

- Widespread use of equilibrium models based on one year's data for projections to 2100
- Deep CO_2 reductions appear in many studies with negligible costs
- GDP-CO_2 relationship is strongly model-dependent (reliability of results?)
- No induced technological change (pre-2001 models), with GDP largely assumed

***Terry Barker, Jonathan Koehler and Marcelo Villena, 'The costs of greenhouse gas abatement: a meta-analysis of post- SRES mitigation scenarios', *Environmental Economics and Policy Studies*, Vol.5, 2002, pp. 135-166.**

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Treatment of technological change in global models

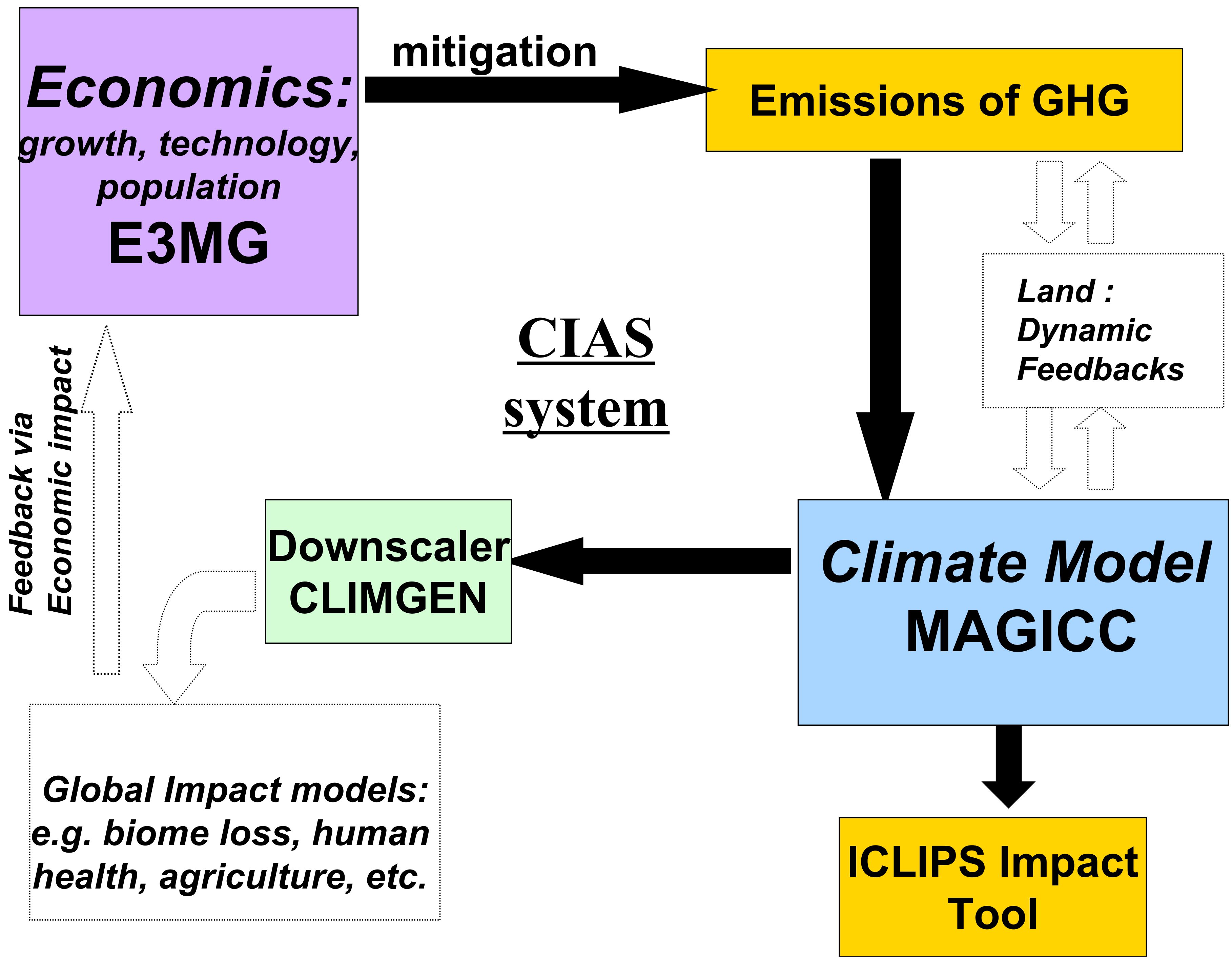
- Exogenous: imposed as a time trend affecting energy demand or GDP growth
- Endogenous: if technology choices are included in the model and their outcome can affect energy demand or economic growth
- Induced: with endogenous technological change, mitigation policies may be able to accelerate that change
  - hence the term induced technological change (ITC)
  - ITC implies endogenous technological change

Induced technological change (ITC) in global models

- Recent literature improves the treatment of technological change in climate models
- Method: introduce learning-by-doing into costs of energy technologies, so that higher real carbon prices induce change
- The reduction in costs takes the form of increased substitution possibilities (e.g. to renewable power or carbon-capture) in equilibrium models
- However economic growth remains largely given by assumption, with general technological change unaffected by the energy sector technologies
- The open question: can increased technological change lead to higher economic growth?

UK Tyndall Centre: modelling of ITC

- The analysis uses the newly developing Tyndall Community Integrated Assessment System (CIAS)
  - Linking economic system, physical climate system and impacts of climate change
- E3MG (Economy-Energy-Environment Model of the Globe) is the key economic component of this system enabling study of technological change and mitigation costs
- ITC is modelled in the context of a theory of demand-led economic growth, partly a result of technological change


Economics:
growth, technology, population
E3MG
mitigation
Emissions of GHG
CIAS system
Land : Dynamic Feedbacks
Feedback via Economic impact
Downscaler CLIMGEN
Climate Model MAGICC
Global Impact models: e.g. biome loss, human health, agriculture, etc.
ICLIPS Impact Tool

E3MG: theory

- Recognises path-dependence and critical role of technology in historical studies of growth
  - Maddison (2001), Denison (1985), Wolff (1994a & b)
- Post-Keynesian theory
  - Kaldor's cumulative causation (1957)
  - Scott's gross-investment as the basis of growth (1989)
  - Uncertainty and expectations are crucial features
- Assumptions
  - increasing returns in some sectors
  - market power varies across sectors
  - behaviour of social groups, not representative agents
  - parameters are location- and time-specific

E3MG: features

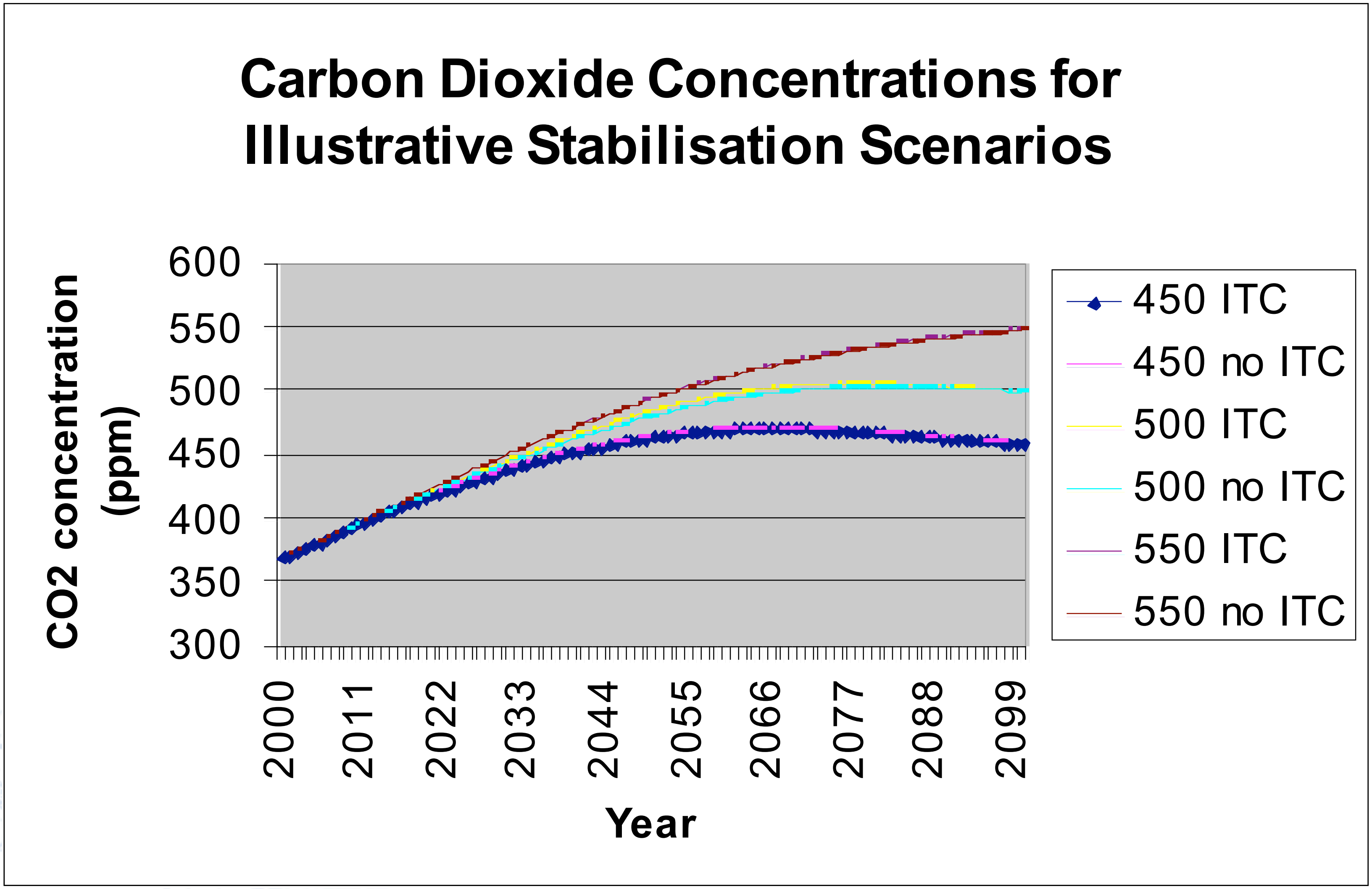
- Structural, econometric, dynamic, non-equilibrium, simulation E3 global model
- Use of cointegration techniques to identify long-run trends from panel data
  - 20 world regions, 21 energy users, 12 energy carriers, 41 industries, 14 atmospheric emissions
- With ITC
  - Anderson & Winne (2004) model of induced change with learning
  - Technological Progress Indicators (TPI) (incl. R&D) in many equations e.g. in 420 energy-use and 820 export equations
- Allowing sector markets to have regional prices
  - except for those for oil and other world commodities

Estimating effects of ITC

- Costs are estimated by comparing baseline and stabilization scenarios
- Technological change is induced by learning-by-doing, reducing costs and accelerating adoption of new technologies
- GHG emission permit prices and carbon tax rates are computed to meet stabilisation targets
- The costs (GDP, loss of fossil fuel output, etc) are associated with these tax rates
- The effects of ITC are calculated by comparing model results with and without the ITC learning curves

The scenarios

- Baseline to 2100 adopted by the International Model Comparison Project
  - (special issue of Energy Journal)
- Climate stabilization targets of 550, 500, 450 ppmv CO_2 concentrations by 2100
- Achieved by global CO_2 permits and taxes
  - Energy sector: permit scheme with 50% auctioned and 50% grandfathered
  - Rest of economy: carbon taxes with rates matching permit prices and all revenues used to reduce consumer taxes
  - Designed to be inflation-neutral, i.e. keep inflation at baseline rates
- Each scenario with and without ITC (8 in all)



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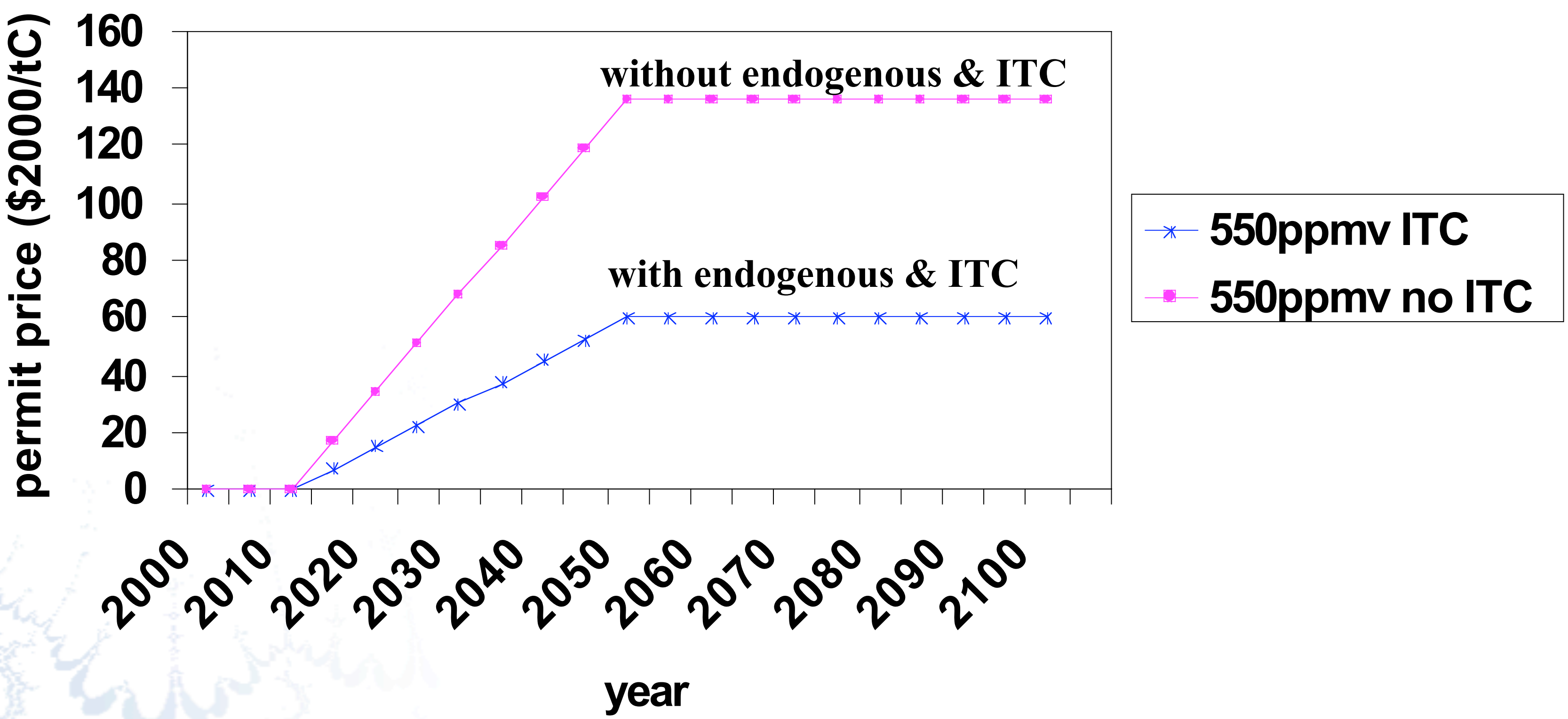
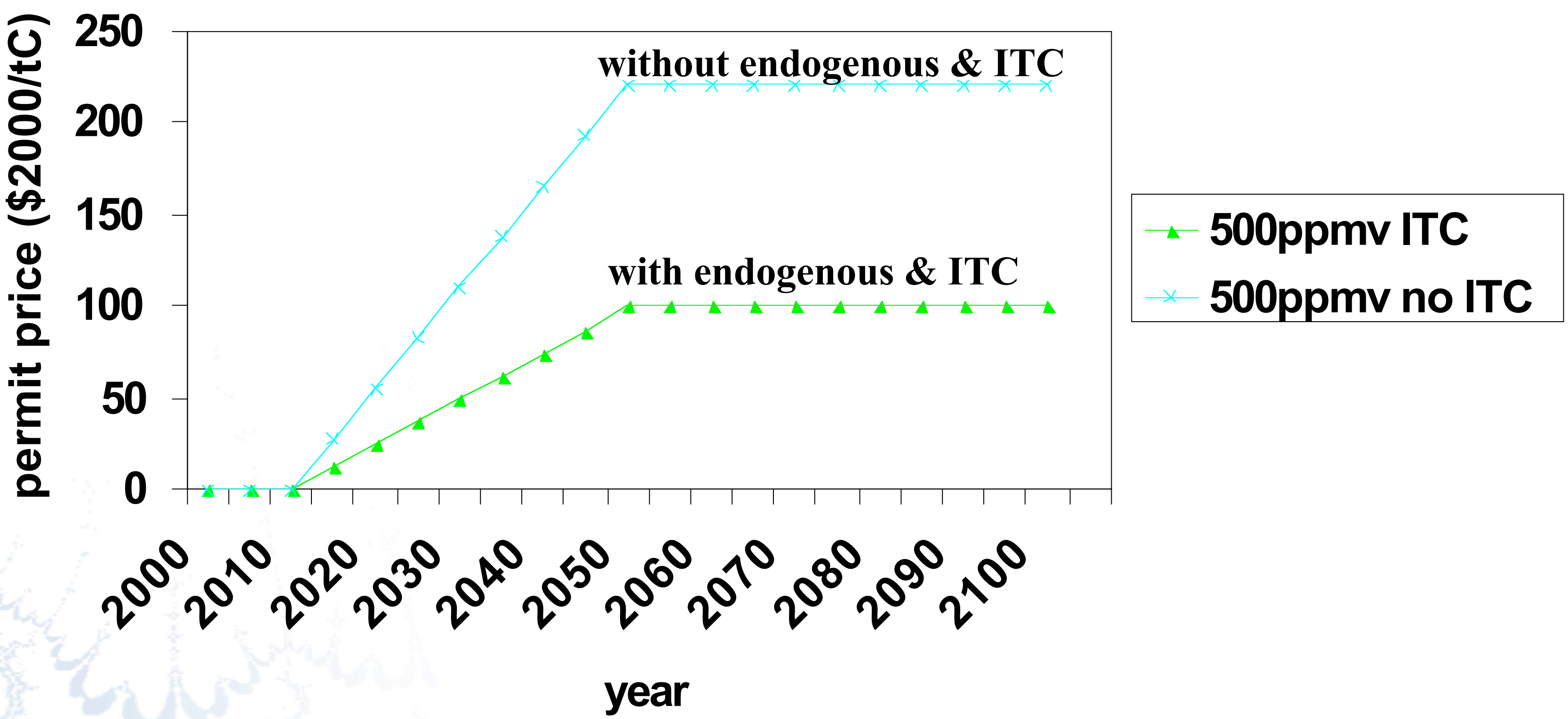
ITC and the global price of carbon: 550 ppmv CO_2 stabilization 2100



Source: E3MG2.1sp2

ITC and the global price of carbon: 500 ppmv CO_2 stabilization 2100



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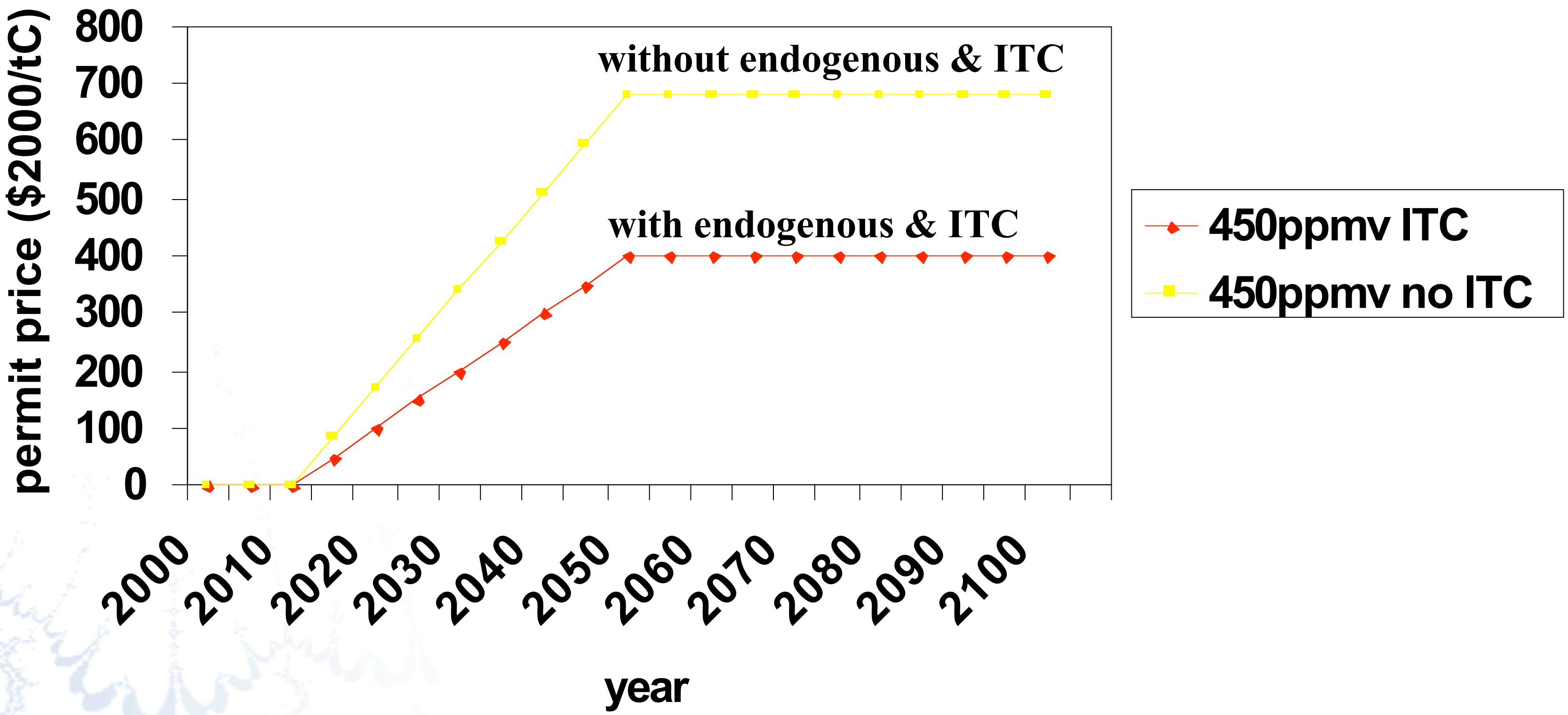
ITC and the global price of carbon: 450 ppmv CO_2 stabilization 2100



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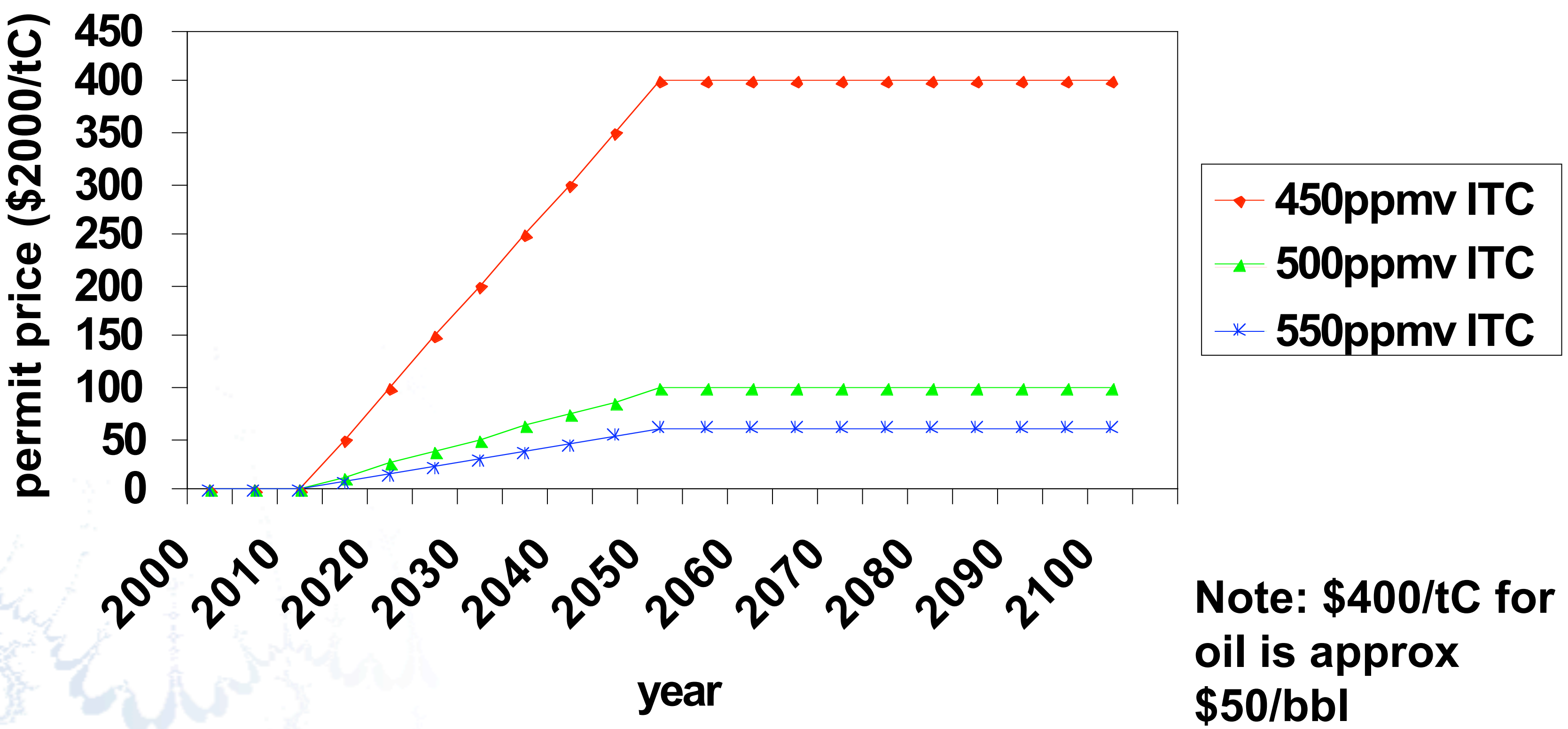
The global price of carbon with ITC: different CO_2 stabilization levels 2100



Note: $400/tC for oil is approx $50/bbl

Source: E3MG2.1sp2

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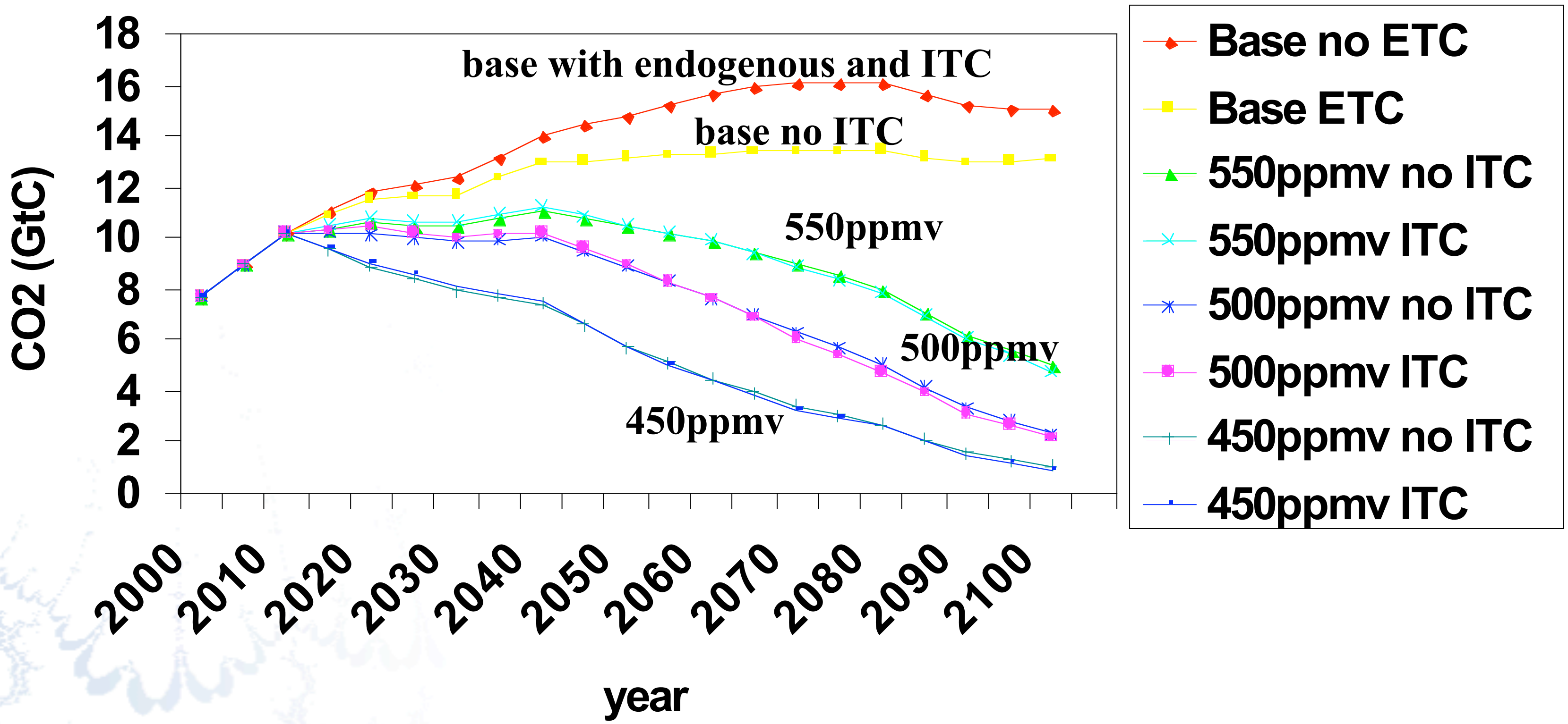
Conclusions of the global price of permits for CO_2 stabilization

- The price of permits for any given level of stabilization is much reduced when the model allows for endogenous technological change
- The price rises according to the stringency of the target
  - 450ppmv price is much higher than 500ppmv price
  - 500ppmv price is higher than 550ppmv price
- These results ~ agree with IPCC TAR (2001), Grubb et al (2002) and Goulder (2004)

Global CO_2 emission pathways and endogenous technological change



Source: E3MG2.0sp1r1,model solutions annually to 2020 and every 10 years to 2100

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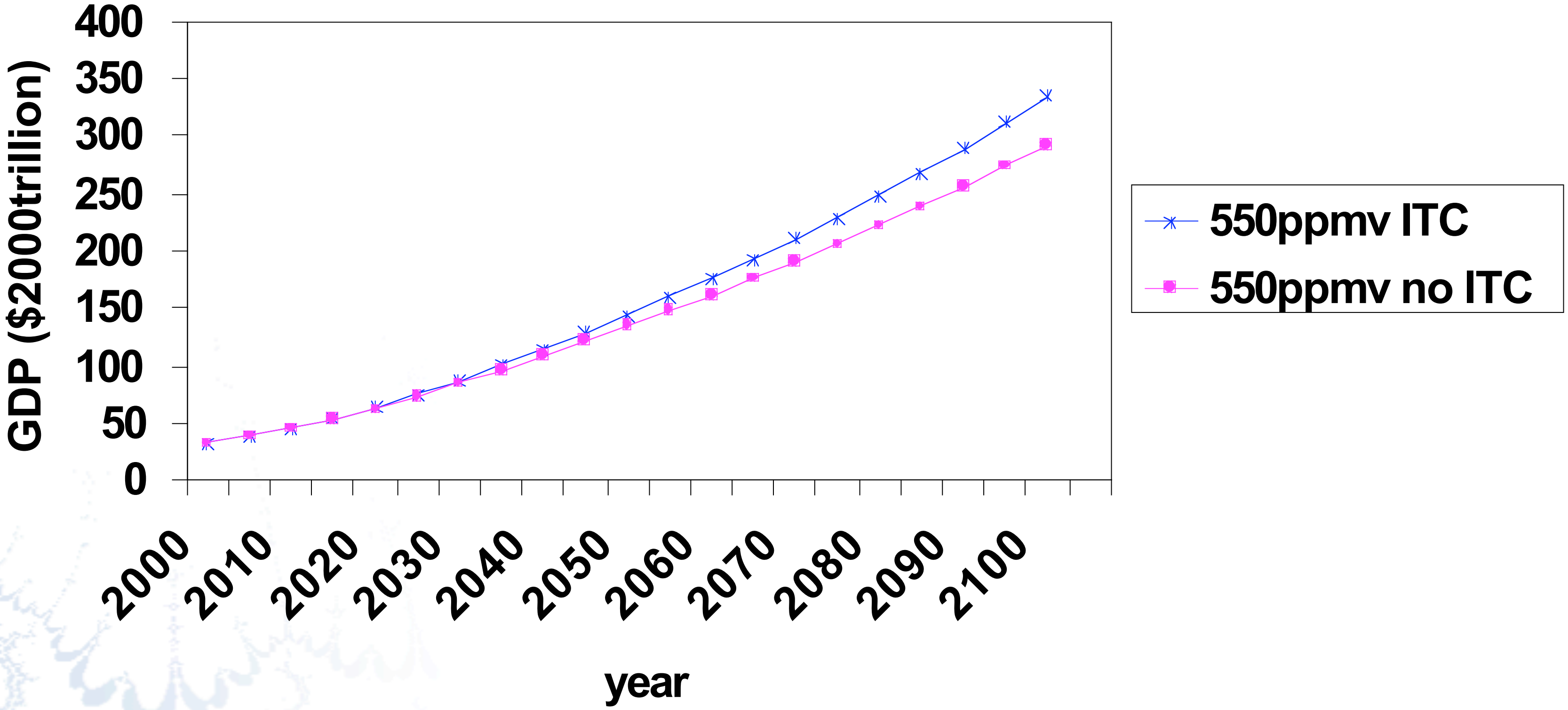
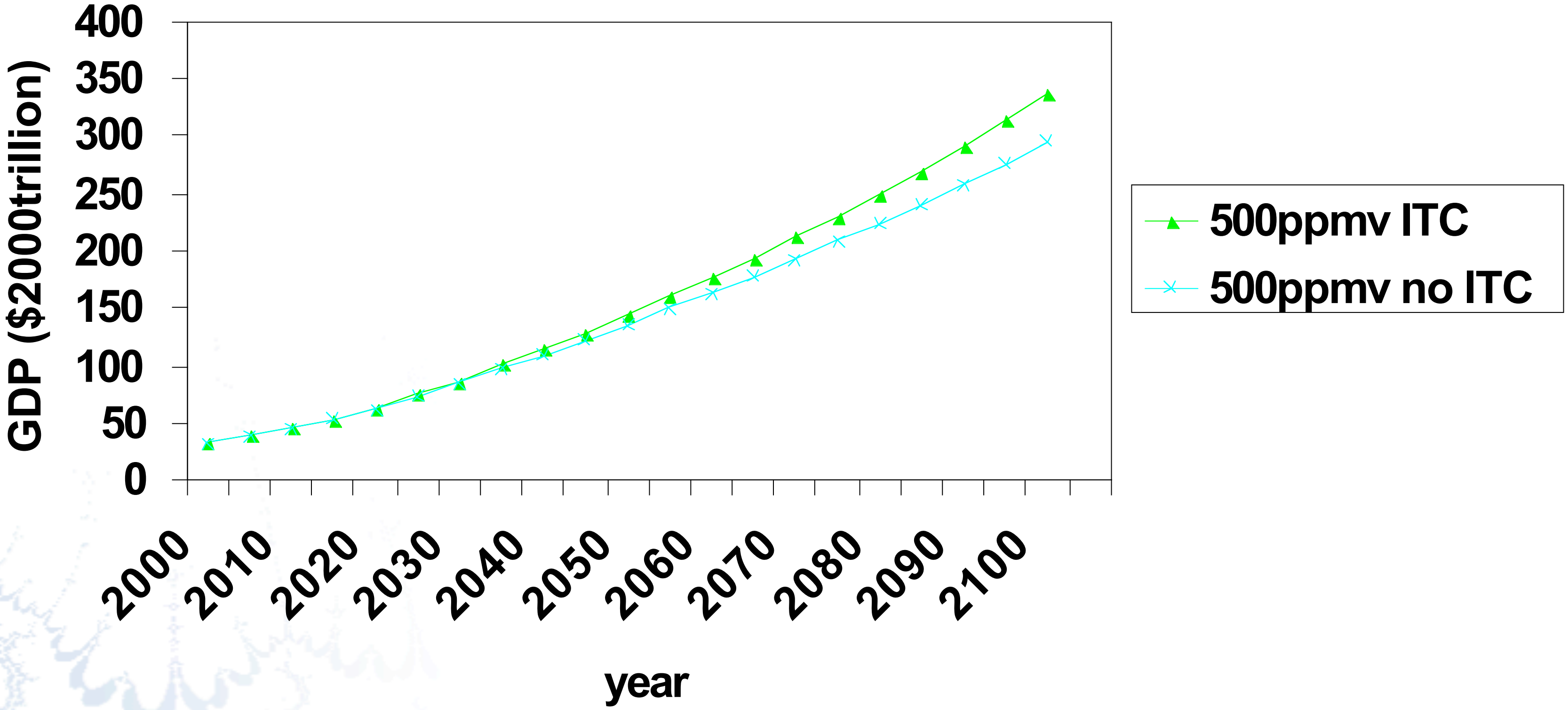
ITC and global GDP: 550 ppmv CO_2 stabilization 2100



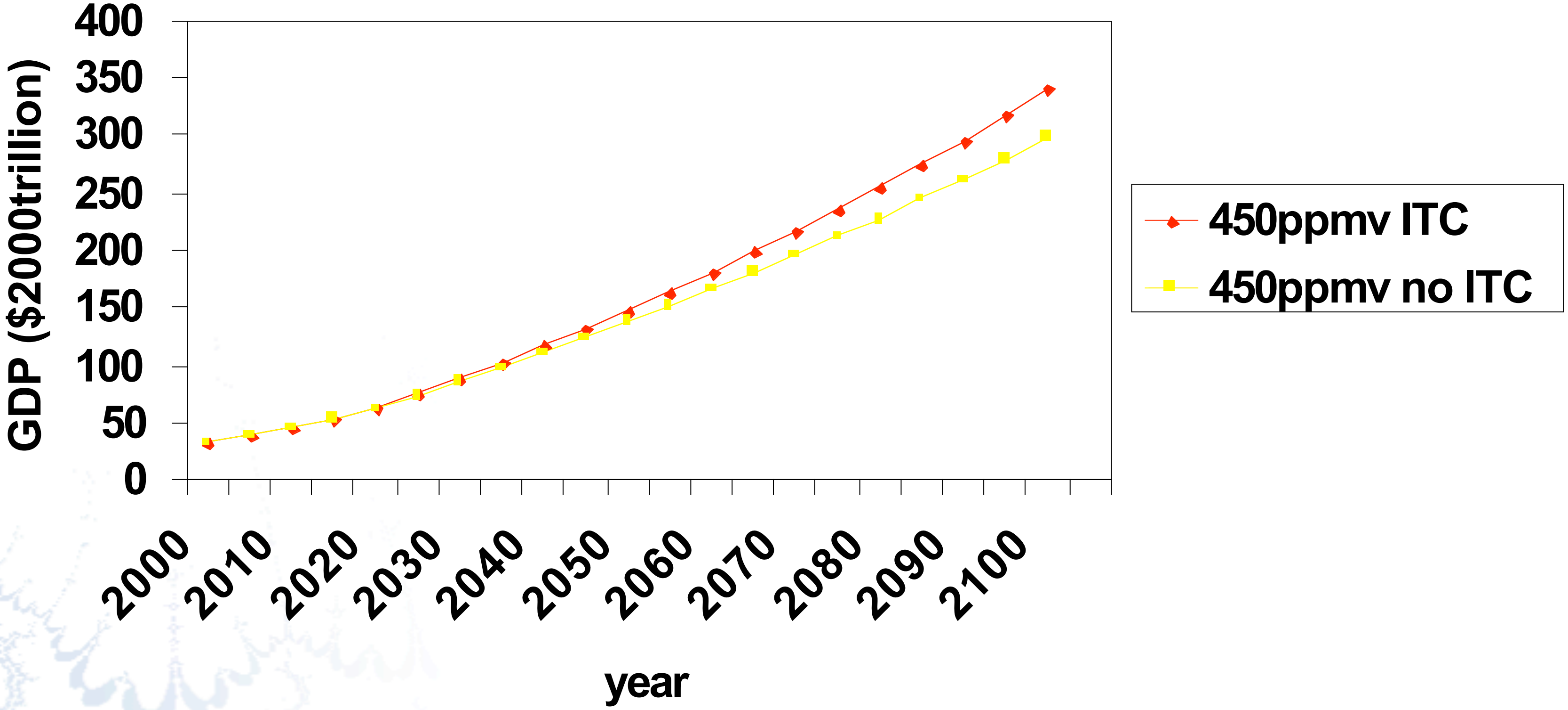
Source: E3MG2.1sp2

ITC and global GDP: 500 ppmv CO_2 stabilization 2100



Source: E3MG2.1sp2

ITC and global GDP: 450 ppmv CO_2 stabilization 2100



Source: E3MG2.1sp2

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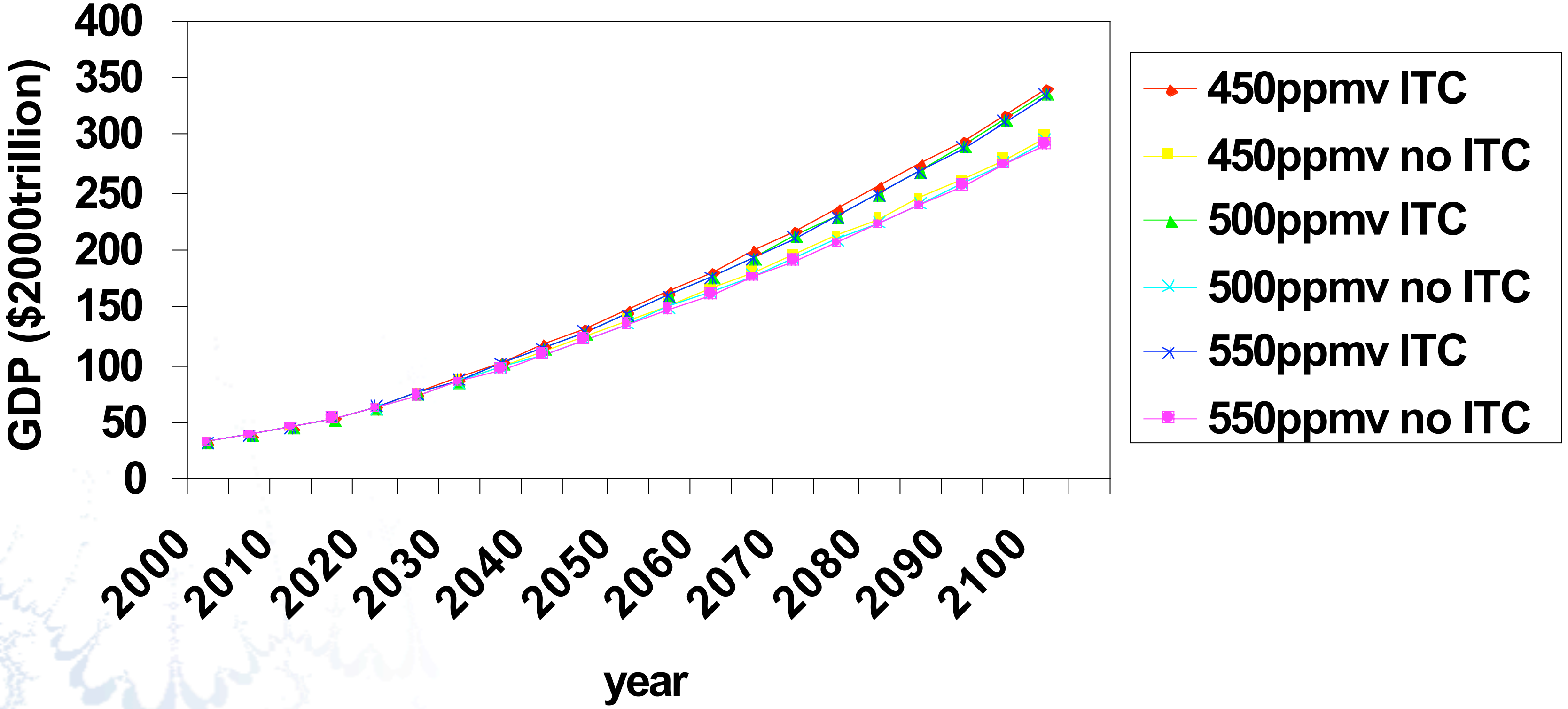
ITC and global GDP: 550, 500 and 450 CO_2 ppmv stabilization 2100



Source: E3MG2.1sp2

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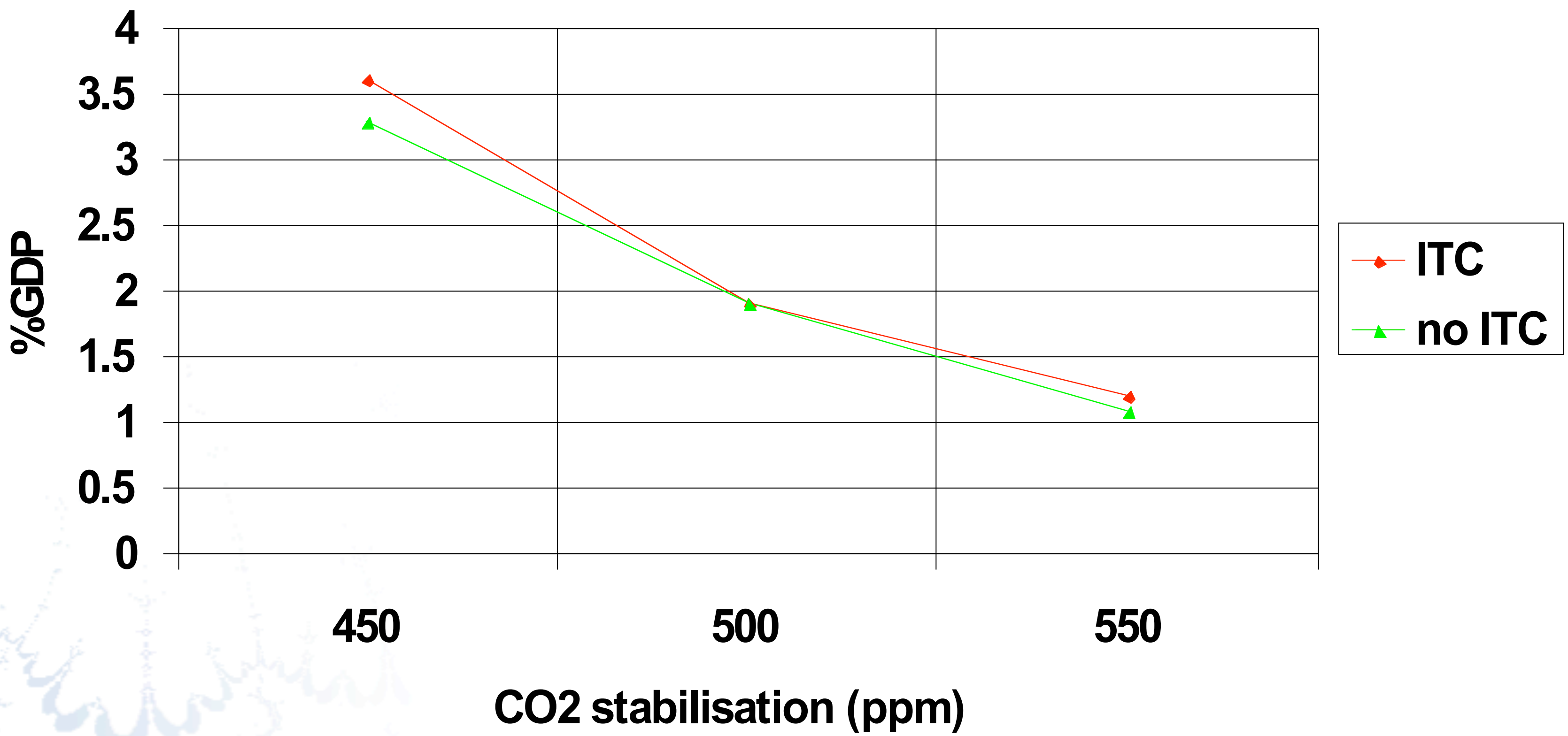
The effects of ITC on GDP by 2100



Source: E3MG2.1sp2, 6 scenarios, % difference from base with and without endogenous technological change by year 2100.
Note: Inflation-neutral revenue recycling; no ancillary benefits.

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Why long-run increases in GDP?

1) The small shares of fossil-fuel energy in global GDP (3 to 5%)
2) Many mitigation scenarios are high-cost because they assume 100 years of high CO_2 emissions in the baseline
   - these imply substantial future funding of investment in coal and unconventional oil
   - this funding has an alternative use: technology-driven energy-saving & renewables
3) Easy substitution to low-GHG-emission products and processes in the long-run with new technologies
4) More technology leads to higher growth

Conclusions (1)

- **Inclusion of induced technological change**
  - significantly reduces the costs of stabilisation
  - in a demand-led model, it leads to higher growth
- **General technological change alone seems unlikely to lead to decarbonisation**
  - improvements in energy efficiency are offset in their effects on CO_2 emissions by the effects of higher growth in exports, incomes and therefore the demand for energy.
- **A wide range of technology and system changes may be induced by higher real costs of carbon**
  - substantial mitigation options may be implemented at relatively low rates of permits/taxes

Conclusions (2)

- If policies are successful in raising real carbon prices, the extra investment is expected to lead to higher global growth and incomes, even for almost complete global decarbonisation to 2100
  - if inflation is unaffected and governmental fiscal rules are followed